Geometric representation

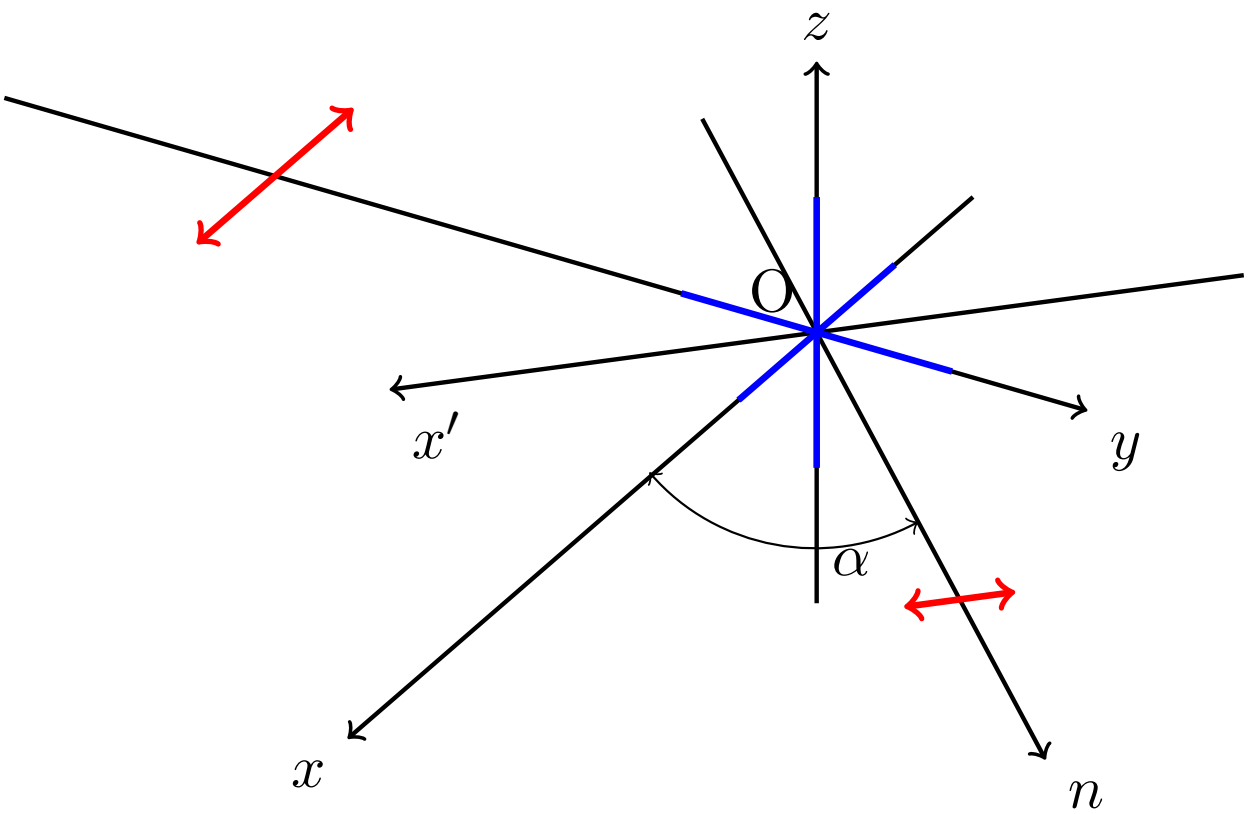
- Broken spherical symmetry (privileged direction) because of
  - anisotropic radiation
  - magnetic field
- Polarization amplitudes of most spectral lines in the sun are of order 10^{-3} : good accuracy needed
- achieved 10^{-5} accuracy with ZIMPOL

Radiation of a non relativistic charge accelelerated free or bound (electron in the classical description with oscillators)

$$\vec{E_{rad}} \propto \vec{n} \times (\vec{n} \times \vec{a}) \tag{1}$$

Geometric representation

Electron accelerated by a force due to the electric field of polarized radiation (Thomson scattering)



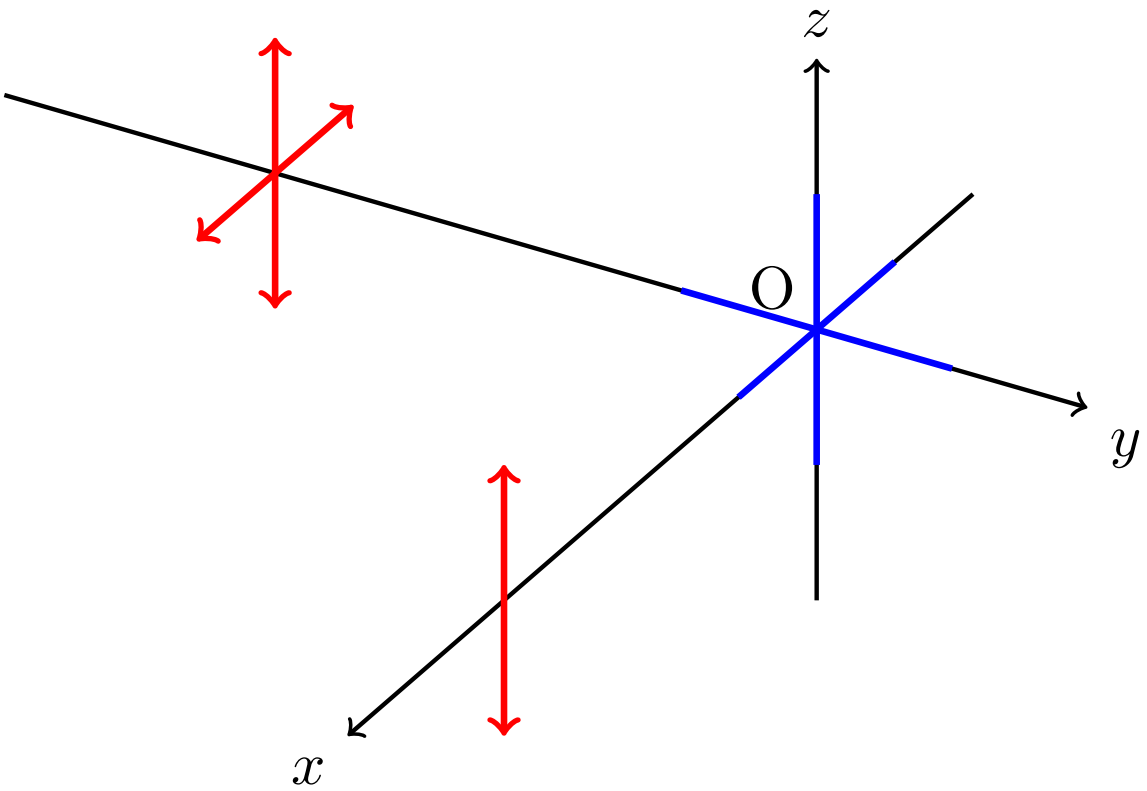
$\vec{x}, \vec{y}, \vec{n}, \vec{x'}$ same plane

Geometric representation

- Anisotropic radiation creates a net dipole moment in scattering atoms or molecules (Rayleigh scattering)
- shorter wavelengths more scattered (blue sky)
- in the Sun: Thomson scattering by electrons and Rayleigh scattering by neutral H

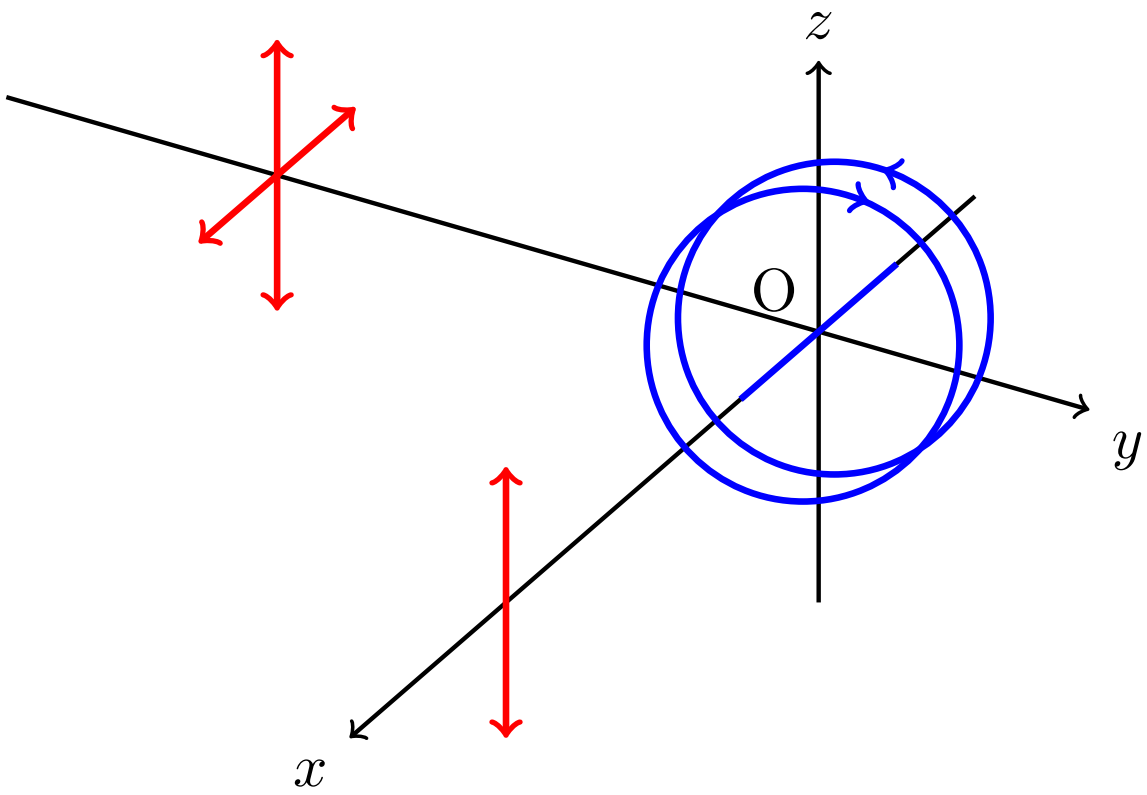
Geometric representation

Incident unpolarized light, cartesian oscillators



Geometric representation

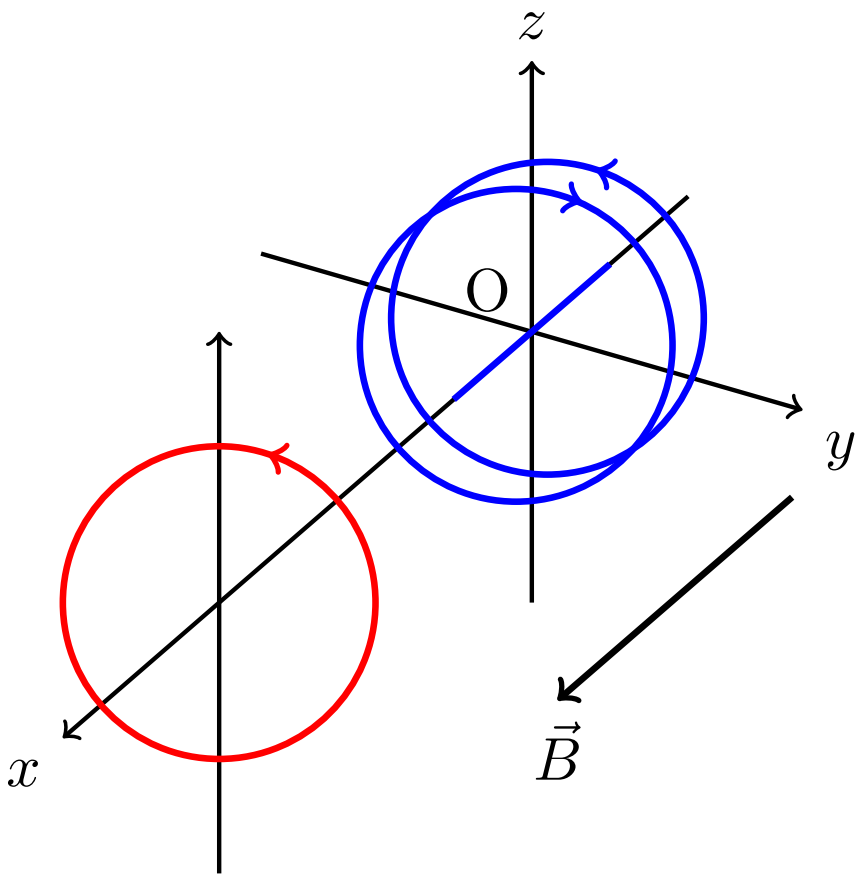
Incident unpolarized light, circular oscillators



coherence between circular oscillators

Geometric representation

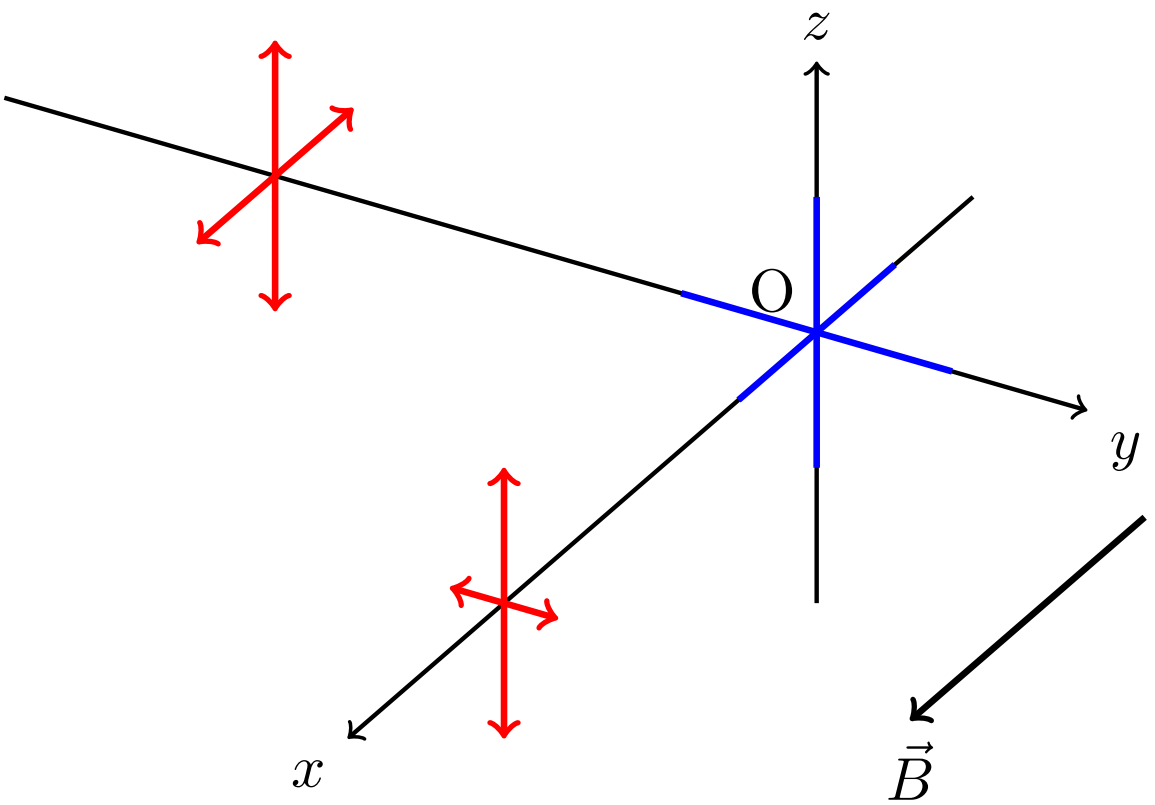
Magnetic field along l.o.s , circular oscillators



ciclotron radiation

Geometric representation

Unpolarized incident light and magnetic field along l.o.s



Geometric representation

'Rosette' effect (circular oscillators)

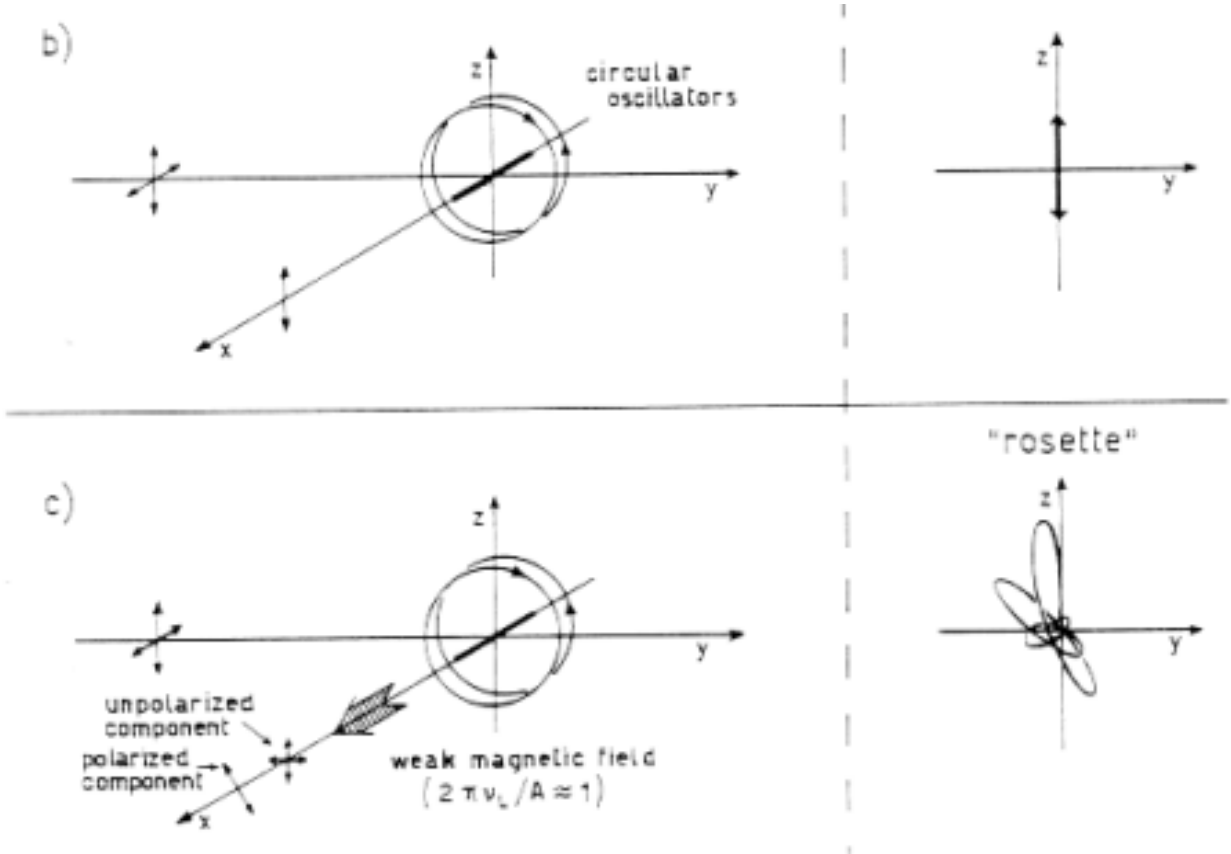
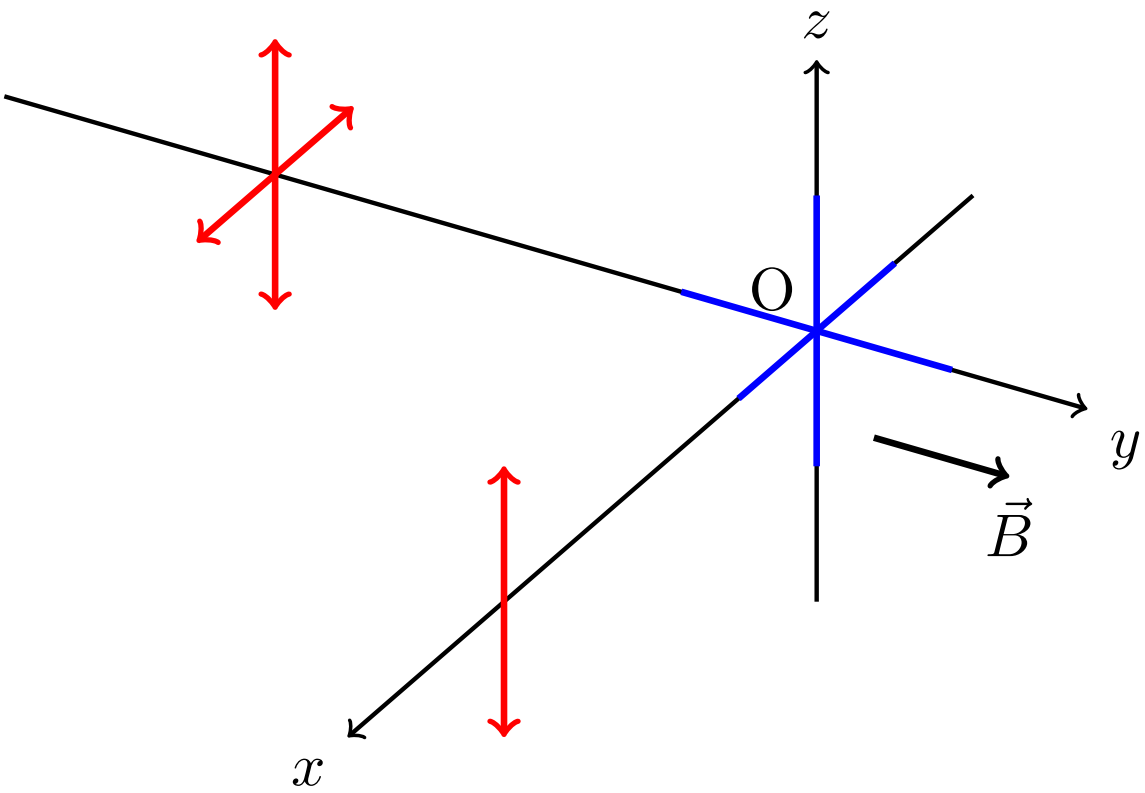


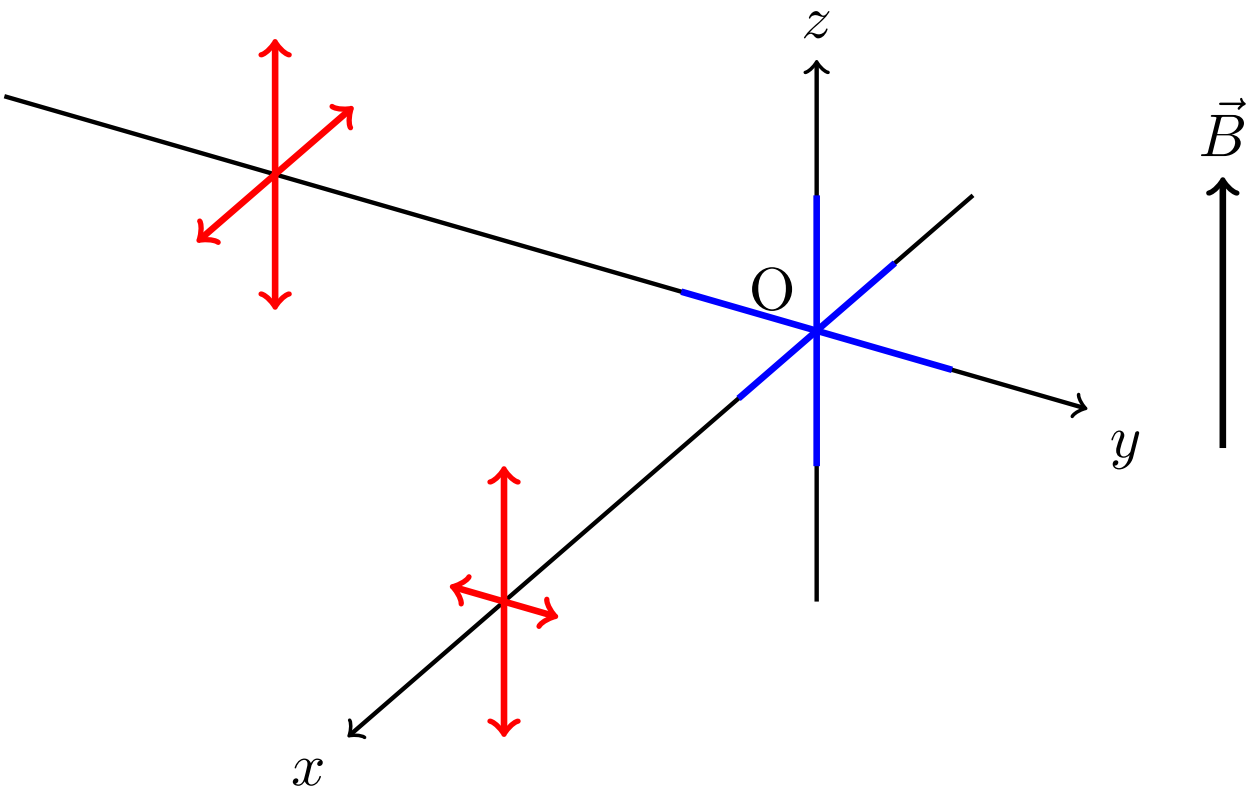
Figure 1: Incoherence in the circular oscillators - Hanle effect

Vertical magnetic field



effect adding to that of the radiation: linear polarization (no V signal, no Hanle effect)

Horrizontal magnetic field, perpendicular to l.o.s.



horrizontal component(Hanle effect), no V signal

Quantic representation (bound electron)

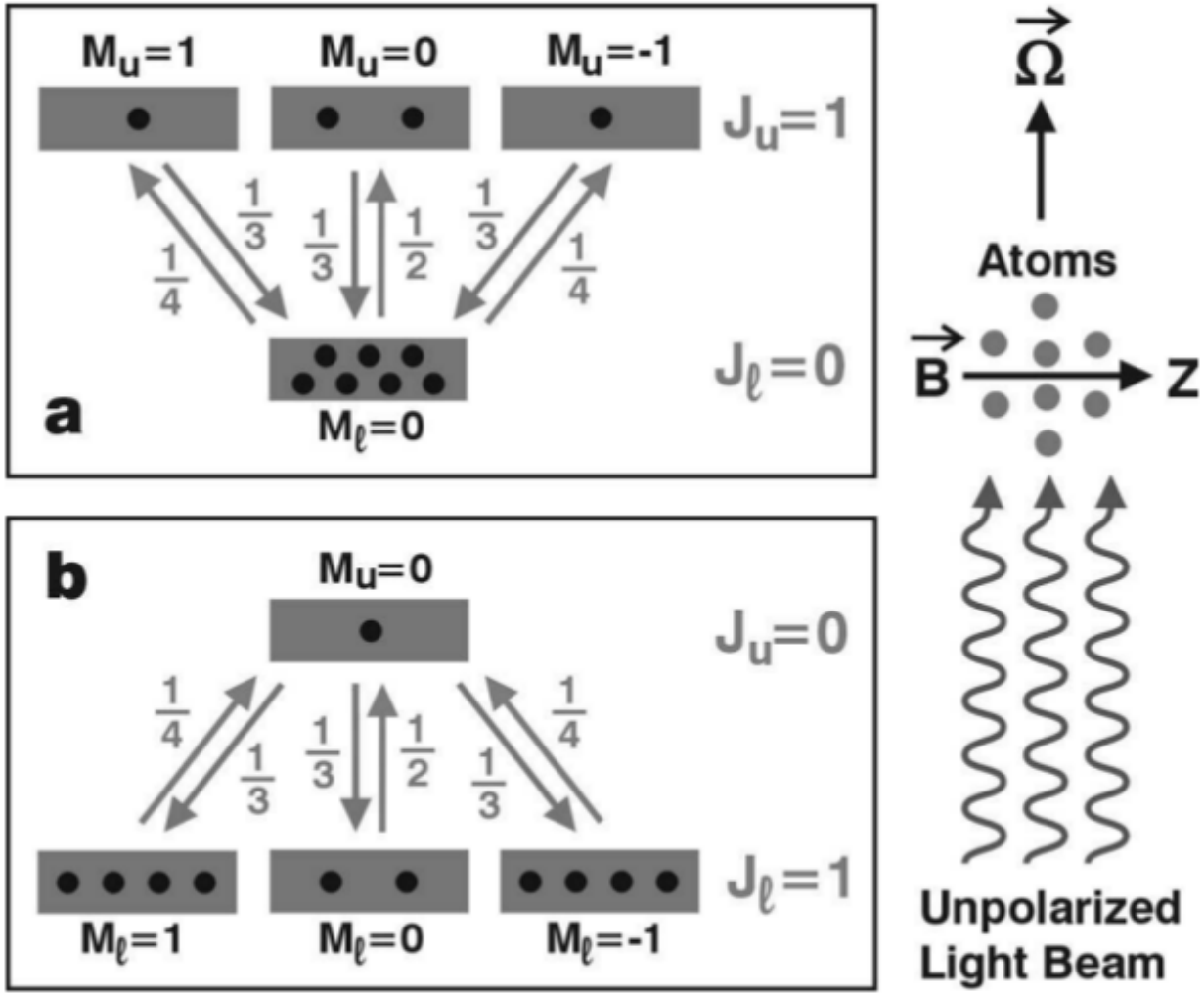


Figure 2: Emission/Absorption

Quantic representation (bound electron)

- Correspondence between atomic transitions and radiation components
  - $\Delta M = 1$, σ_+ $(\nu + \nu_L)$, clockwise oscillator
  - $\Delta M = 0$, π (ν), x oscillator
  - $\Delta M = -1$, σ_- $(\nu - \nu_L)$, anticlockwise oscillator
- similar mechanism(Fig 2 b) for absorption lines (experimetally done by observing same line in filaments: absorption and in prominences: emission)
- Anisotropic radiation populates/depopulates twice M=0 sublevel
- Magnetic field:
  - splitting of energy level J into 2J+1 sublevels (Zeeman effect)
  - creates incoherence between population of levels corresponding to σ components which leads to incoherence in the 2 circular oscillators (Hanle effect)

Second specter of the sun

With the same geometry: Q represents linear polarization parallel to the closest limb

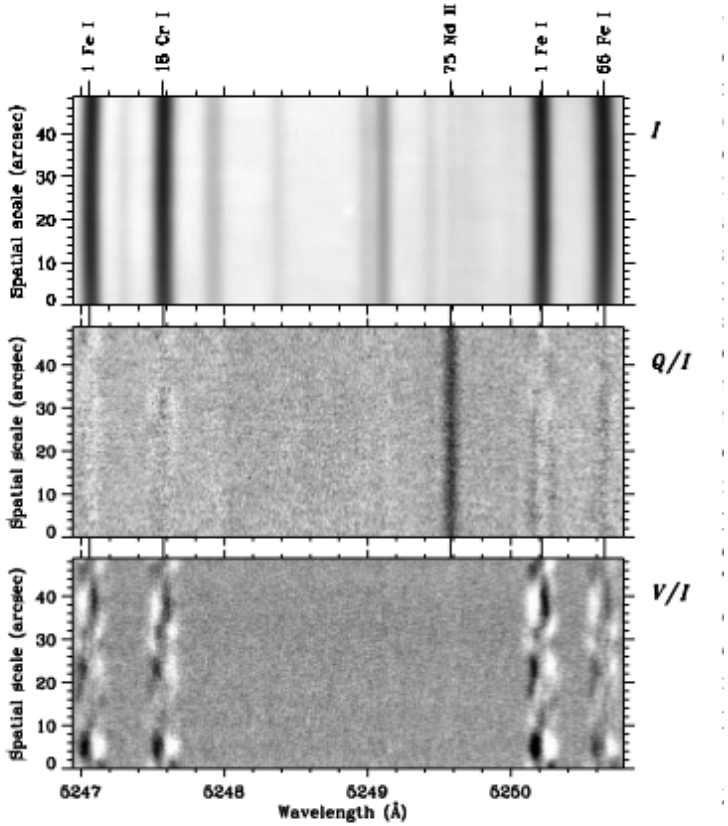


Fig. 1. Examples of the different characters of the ordinary intensity spectrum (Stokes I, top diagram), the linearly polarized spectrum (Stokes Q/I, here called the "second solar spectrum"), and the circularly polarized spectrum (Stokes V/I, bottom diagram). While the circular polarization shows Zeeman-effect signatures due to magnetic canopies at the supergranulation size scale, the linear polarization is dominated by the signature of coherent scattering, which here unexpectedly is due to a transition in ionized neodymium. The recording

Second specter of the sun

assume U = V = 0 $\implies$ no $U, V -> Q$ cross talk
all signals divided by I (no zero I), no $I -> Q$ cross talk
$Q -> I, U, V$ would reduce Q ampl by 0.5%
Q signal generated by other mechanisms (is the assumption $U, V -> Q$ cross talk = 0 correct?)

- instrumental
  - atmospheric seeing and CCD noise: resolved by modulating the signal at high frequency: 2 modulators one at 42 kHz and 84 kHz
  - polarization by reflection (in the plane perpendicular to the plane of reflection for angles bigger than a certain angle which depends on refraction indices) - not important
- real effects of magnetic field
  - position near the (geographic) north/south pole where influence of the magnetic field is smaller
  - cross talk Stokes V generated by the magnetic field along l.o.s recognized (sign reversed periodically in spatial repr.)
  - vertical magnetic field - no effect, horrizontal magnetic field perpendicular to line of sight - not considered

Observation details

- instrument: ZIMPOL, the Zurich Imaging Stokes Polarimeter
- telescope: McMath-Pierce(National Solar Observatory (Kitt Peak, USA).)
- accuracy: 10^{-5}
- April 1995, slit positioned 5 seconds of arc inside the north polar limb (where the cosine μ of the heliocentric angle is 0.1)
- 10 minutes exposure time